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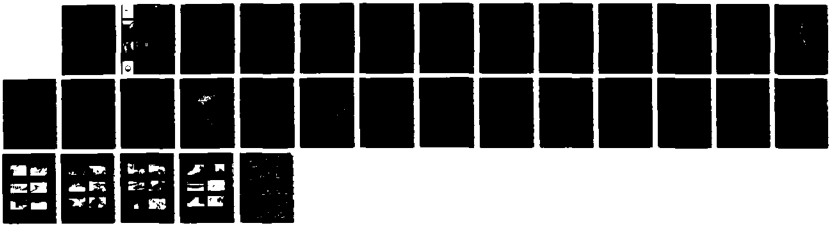

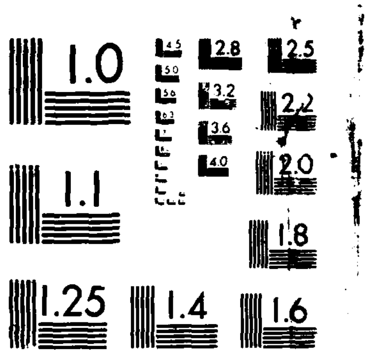

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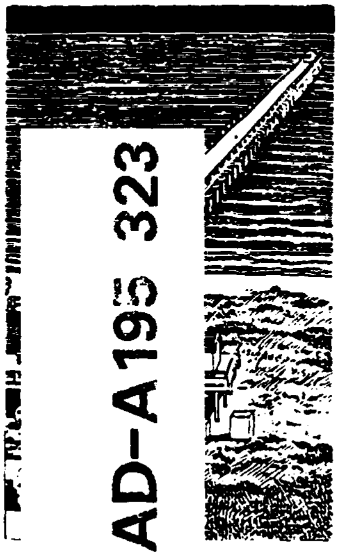

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MISCELLANEOUS PAPER CERC-88-6

MONITORING COMPLETED COASTAL PROJECTS: OPERATIONAL ASSESSMENT OF FLOATING BREAKWATERS, PUGET SOUND, WASHINGTON

by

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April 1988

Final Report

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Under the Monitoring Completed Coastal Projects Program, an operational assessment of six floating breakwaters in Puget Sound, Washington, was performed between October 1984 and September 1986. Onsite data on the performance and durability of floating breakwaters were gathered, and an analysis of the operational experience is documented herein.

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PREFACE

Funding for the study herein was provided through the Monitoring Completed Coastal Projects Program, Project Operations and Maintenance, Office of the Chief of Engineers (OCE), US Army Corps of Engineers, to the Coastal Engineering Research Center (CERC) at the US Army Engineer Waterways Experiment Station (CEWES). Mr. John J. Lockhart, Jr., is OCE Technical Monitor.

This report was prepared by Messrs. Eric E. Nelson, US Army Engineer District, Seattle, and J. Michael Hemsley, Prototype Measurement and Analysis Branch, Engineering Development Division (CD), CERC, under direct supervision of Mr. Thomas W. Richardson, Chief, CD; and under general supervision of Dr. James R. Houston and Mr. Charles C. Calhoun, Jr., Chief and Assistant Chief, CERC, respectively. This report was edited by Ms. Shirley A. J. Hanshaw, Information Products Division, Information Technology Laboratory, WES.

During report publication COL Dwayne G. Lee, CE, was Commander and Director of CEWES. Dr. Robert W. Whalin was Technical Director.

CONTENTS

CONVERSION FACTORS, NON-SI TO SI (METRIC) UNITS OF MEASUREMENT

Non-SI units of measurement used in this report can be converted to SI (metric) units as follows:

Multiply	By	To Obtain
feet	0.3048	metres
inches	2.54	centimetres
knots (international)	0.5144444	metres per second
miles (US statute)	1.609347	kilometres
pounds (force)	4.448222	newtons
pounds (mass)	0.4535924	kilograms
tons (2,000 pounds, mass)	907.1847	kilograms

MONITORING COMPLETED COASTAL PROJECTS: OPERATIONAL ASSESSMENT OF FLOATING BREAKWATERS, PUGET SOUND, WASHINGTON

PART I. INTRODUCTION

Background

1. Operational problems with floating breakwaters have often been the rule rather than the exception. Because of these problems, the US Army Engineer District, Seattle (CENPS), conducted the Floating Breakwater Operational Assessment under the Monitoring Completed Coastal Projects (MCCP) Program in fiscal year 1985. The MCCP Program, a national program for intensive monitoring of selected Civil Works projects on the coast and Great Lakes shores of the United States, has as a goal the reduction of operations and maintenance expenditures for Corps of Engineers (Corps) coastal projects by comparing their behavior and performance with design predictions and then using this information to improve the Corps' design methods. Additionally, the monitoring program will help identify concerns that research and development should address.

2. To develop direction for the MCCP Program, the Corps established an ad hoc committee of coastal engineers and scientists. The committee formulated the program's objectives, developed its operational philosophy, recommended funding levels, and established criteria and procedures for project selection. A significant result of their efforts was the following prioritized listing of problem areas to be addressed which constituted, essentially, a listing of the program's areas of interest:

- a. Shoreline and nearshore current response to coastal structures.
- b. Wave transmission by overtopping.
- c. Prediction of the controlling cross section at inlet navigation channels.
- d. Wave attenuation by breakwaters (submerged and floating).
- e. Bypassing at jettied and unjettied inlets.
- f. Wave refraction and steepening by currents.
- g. Beach-fill project monitoring.
- h. Stability of rubble structures and investigations to determine causes of failure.

i. Comparison of preconstruction and postconstruction sediment budgets.

j. Wave and current effects on navigation.

k. Dynamics of floating structures.

l. Wave reflection.

m. Effects of construction techniques on scour and deposition near coastal structures.

n. Diffraction around prototype structures.

o. Wave runup on structures.

p. Onshore/offshore sediment movement near coastal structures.

q. Harbor oscillations.

r. Wave transmission through structures.

s. Material life cycle.

t. Ice effects on structures and beaches.

u. Model study verification.

v. Wave translation.

w. Construction methods.

The initial list compiled had only the first 20 items. As the program has grown, so has the list; the final three items were recently added.

3. The selection process for monitoring projects envisioned by the ad hoc committee members has worked well since the first projects were nominated in 1981. Periodically, the Corps' coastal field offices are invited to nominate projects for monitoring under the program. Nominations are reviewed and prioritized by a selection committee comprised of representatives from the Office of the Chief of Engineers (OCE), US Army Engineer Waterways Experiment Station (CEWES) Coastal Engineering Research Center (CERC), and coastal division offices. Final selection is based on the prioritized list of projects and available funding.

4. While guidance is provided by OCE, management of the program rests with CERC. Operation of the program is a cooperative effort between CERC and individual Corps district and division offices. Development of the monitoring plan and conduct of data collection depend on the combined resources of CERC and the districts.

Objectives

5. Objectives of the Floating Breakwater Operational Assessment are to

obtain onsite data on the performance and durability of floating breakwaters and to document "every day" or operational experience such as recreational use, transient moorage difficulties/preferences, and wave/wake transmission, diffraction, and reflection problems. Two of the breakwaters monitored were at the recently completed Corps projects at Friday Harbor and East Bay (Olympia), Washington. A third breakwater, constructed of pipe and scrap tires by the Corps for the Floating Breakwater Prototype Test Program* was surplused and is now located at a marina near Johnson Point in southern Puget Sound.

6. Additionally, field inspections and interviews with the managers of three other non-Corps floating breakwater installations in the Puget Sound area were conducted to broaden the information base. These breakwaters are located at Brownsville, Washington; the University of Washington Laboratory at Friday Harbor, Washington; and Semiahmoo Marina at Drayton Harbor, Blaine, Washington. The locations of all breakwaters are shown in Figure 1.

Scope

7. The report herein discusses data collected on the six floating breakwaters at Puget Sound. Except for a recording anemometer at the Friday Harbor project, this operational assessment did not require the use of instrumentation. Rather, observations and photographs taken by the harbor master or marine manager, supplemented with periodic inspections by district personnel, were considered adequate to provide necessary data. Emphasis was placed on gathering data from Corps projects at Friday Harbor and East Bay and from the marina which salvaged the pipe-tire breakwater that was used during the Floating Breakwater Phototype Test.

8. At Friday Harbor, the site of the most intense effort, underwater inspections were planned to assess the effectiveness of the cathodic protection system on the anchor lines. As will be described in Part III, this inspection resulted in the discovery and correction of a potentially serious problem with the breakwater mooring system. Wherever possible, information on design parameters was obtained to provide additional input to assess the structures' performance.

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* E. E. Nelson, and L. L. Broderick. 1986 (Mar). "Floating Breakwater Prototype Test Program: Seattle, Washington," Miscellaneous Paper CERC-86-3, US Army Engineer Waterways Experiment Station, Vicksburg, Miss.

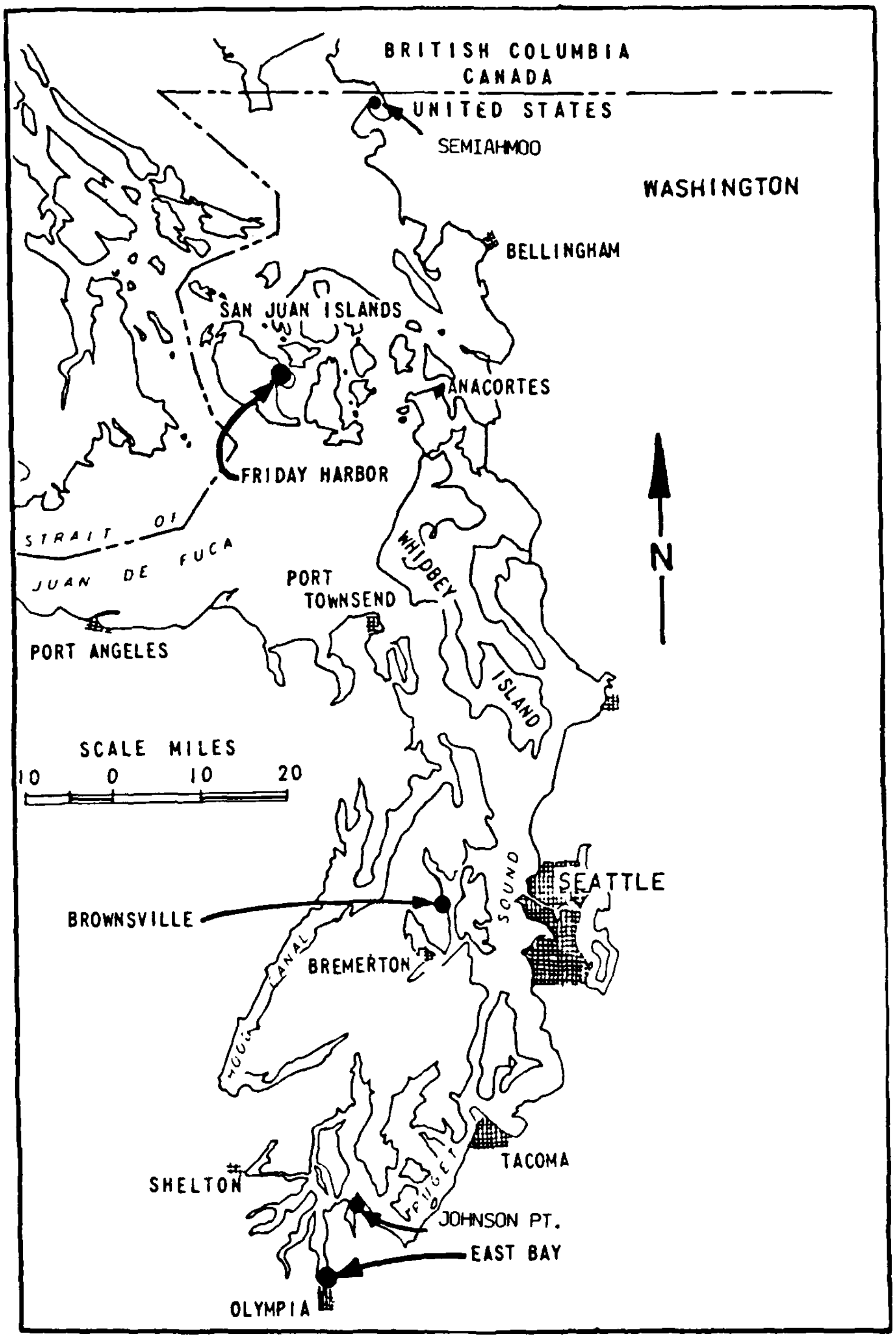

Figure 1. Location map, MCCP Program floating breakwater sites

PART II: DESCRIPTION OF PROJECTS

9. Three of the floating breakwaters observed were originally constructed by the Corps. These were the concrete structures at Friday Harbor and East Bay Marina (Olympia), Washington, and the pipe-tire structure salvaged and installed at Zittle's Marina near Johnson Point in southern Puget Sound. Three non-Corps structures observed were concrete breakwaters at Brownsville, Washington; the University of Washington Laboratory at Friday Harbor, Washington; and Semiahmoo Marina at Drayton Harbor, Blaine, Washington.

Port of Friday Harbor Marina

10. The 580-boat marina at Friday Harbor is located on the eastern shore of San Juan Island on the inland waters of northwestern Washington, about 32 miles* east of Victoria, British Columbia, and 69 miles north of Seattle, Washington. The 1,600-ft-long floating breakwater was constructed and installed by the Corps in 1984 (Photo 1).

11. Tides at Friday Harbor are typical of those along the Pacific coast of North America. They are mixed with two unequal highs and lows each day. Tidal range datums for Friday Harbor, as published by the National Oceanographic and Atmospheric Administration's National Ocean Service (NOS), are shown in Table 1.

12. Water depth at the site varies between 40 and 50 ft; bottom materials consist of a surface layer of very soft silt overlying relatively firm silts, sands, and clays. Current studies conducted by CENPS in August 1979 show that maximum current velocities at Friday Harbor are northerly at less than 1.5 fps during spring ebb tide. Currents are less than 1.0 fps during flood tide and are southerly. The greatest flow enters and exits via the eastern opening between San Juan Island and Brown Island just to the north.

13. During summer, winds in the vicinity of San Juan Island are light and predominantly from the south. Winter storms can produce winds in excess of 50 mph from the northeast. Exposure to wind-generated waves is from two

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* A table of factors for converting non-SI units of measurement to SI (metric) units is presented on page 3.

Table 1

Tidal Datums, Friday Harbor

Datum Plane	Elevation, ft*
Highest estimated tide (30 Dec 52)	11.00
Mean higher high water (MHHW)	7.70
Mean high water (MHW)	7.00
Mean (half) tide level (M(half)TL)	4.75
Mean low water (MLW)	2.50
Mean lower low water (MLLW)	0.00
Lowest tide (15 Jan 49)	-3.80

* Feet referenced to MLLW.

windows on either side of Brown Island. Winds from the northeast have an effective fetch of 2.25 miles, while those from the southeast have an effective fetch of 1 mile. Design wave conditions exhibit a significant wave height H_s of 3.2 ft and period T of 3.2 sec from the northeast and H_s of 2.7 ft and T of 2.6 sec from the southeast.

14. The breakwater consists of five rectangular concrete pontoons, three of which are 330 ft long by 21 ft wide by 6 ft high. Two pontoons are 16 ft wide by 5.5 ft high (Figure 2**). Breakwater anchors are 52 steel H-piles embedded their full length. Anchor lines consist of 1-3/8-in.-diam galvanized bridge rope with 30 ft of 1-1/4-in. stud link chain at the upper end. Anchor line lengths were sized to provide a scope of 4:1 to 5:1. A 2,000-lb concrete clump weight is attached approximately 50 ft from the upper end of each anchor line. Anchor line initial tension is approximately 10,000 lb. Three large aluminum anodes were attached to each anchor line to prevent corrosion (Figure 3).

University of Washington Friday Harbor Laboratory

15. The floating breakwater at the University of Washington Oceanographic Laboratory is about a half mile north of the Port of Friday Harbor. The site has an open fetch to the east of about 4 miles.

** US Army Engineer District, Seattle. 1981 (Apr). "Friday Harbor Marina Expansion Final Detailed Project Report and Final Environmental Assessment," Seattle, Wash.

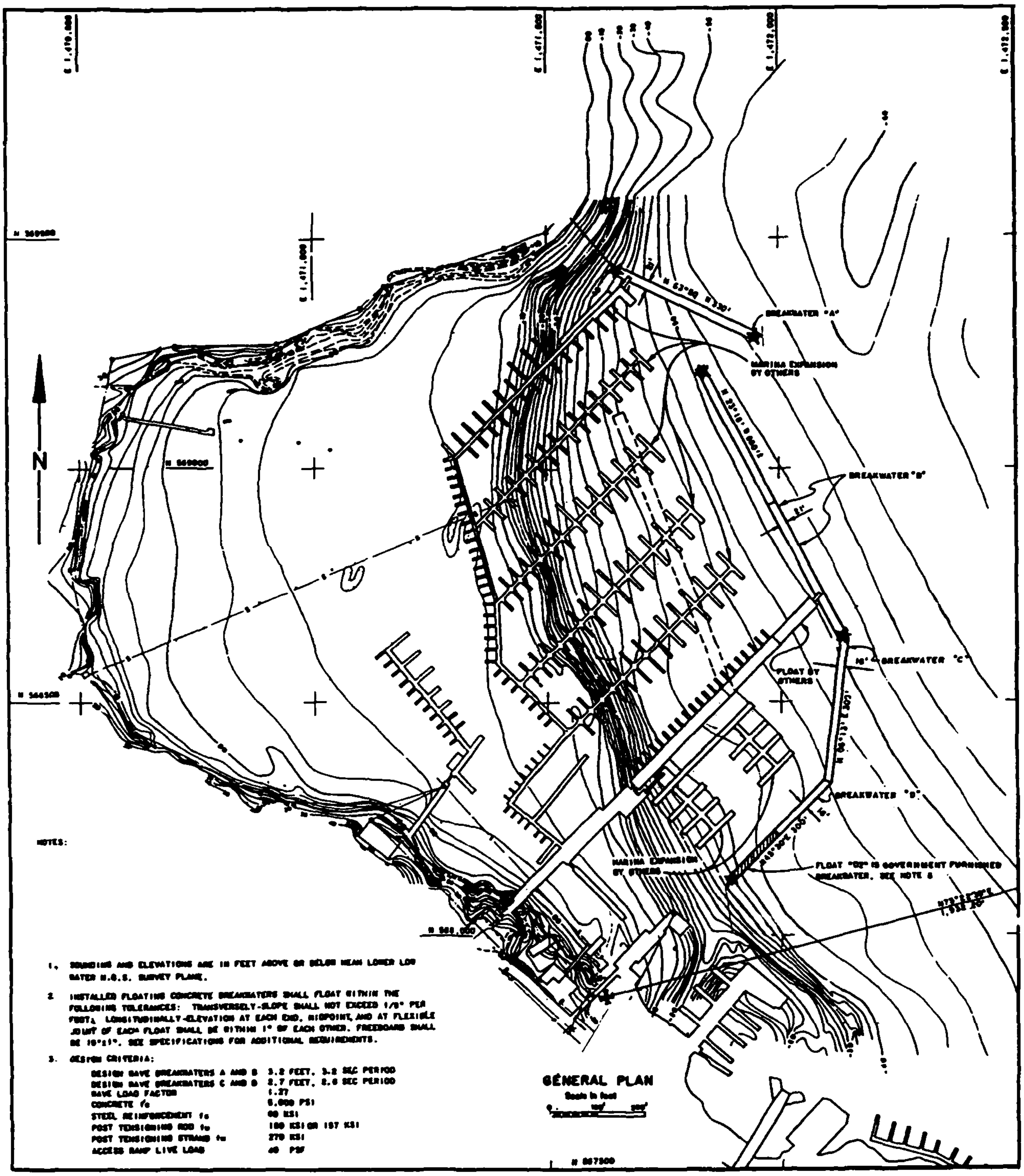

Figure 2. Friday Harbor Marina breakwater layout

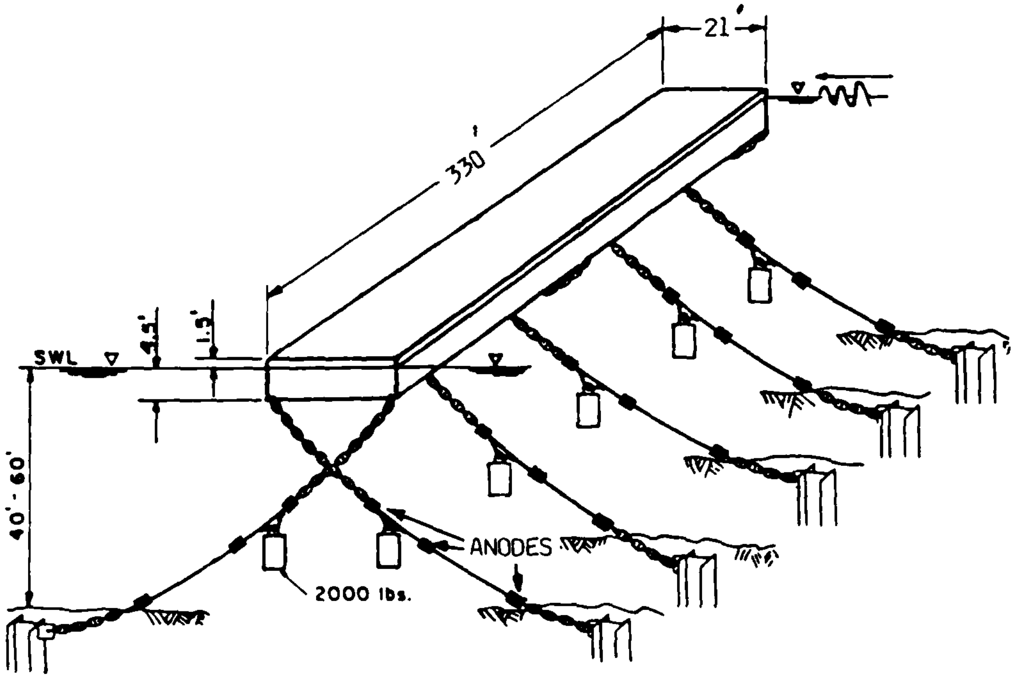

Figure 3. Schematic of breakwater unit and anchor system for Friday Harbor (swl = still-water line)

16. Tide conditions are the same as for the Corps breakwater at Friday Harbor, but the site is more exposed to the east. Design paremeters were a 46-knot wind fetch-limited significant wave height of 3.0 ft, a period of 3.5 sec, and a current of 1.5 knots. Boat wakes of 1 to 2 ft are common. Water depth varies between 10 and 60 ft.

17. Installed in 1979, the breakwater is a reinforced concrete caisson cast over a polystyrene foam core with a cross section of 4.5 by 15 ft, with a design freeboard of 18 in. It is L-shaped with two 130-ft sections on the long leg parallel to the east-west shore and a third 130-ft section on the short north-south leg (Photo 2). The anchor system is laid out to maint .. a 6-ft space between the sections to avoid linkage and impact problems. Short gangways provide access between units. The breakwaters are used as staging areas for handling nets and other gear as well as to provide a protected mooring area.

18. Each float is independently anchored by 1-in.-diam-stud-link-chain

anchor lines attached to the four corners of each section. Each corner line is oriented at a 45-deg angle to the breakwater. Three-ton clump weights are attached to the anchor lines, except the landward line on the north-south leg. Because bottom conditions at the site consist of a shallow covering of sand over bedrock, only gravity anchors were considered. The main anchors are 8- by 8- by 6-ft concrete blocks.

East Bay Marina, Olympia, Washington

19. The Corps' breakwater at East Bay, Olympia, Washington, is located at the southernmost terminus of Puget Sound, approximately 90 miles south of Seattle. Tidal range datums for Olympia Harbor, as published by the NOS, are shown in Table 2. The marina site is exposed to wind waves generated from the northwest through northeast directions. Land masses protect the site from all other directions. Design wave height at the breakwater is a 2.0-ft significant wave with a period of 2.8 sec from the north-northwest.

Table 2

Tidal Datums, East Bay Marina

Datum Plane	Elevation, ft*
Highest tide (15 Dec 77)	18.22
MHHW	14.45
MHW	13.51
M(half)TL	8.28
MLW	3.04
MLLW	0.00
Lowest tide (est.)	-4.70

* Feet referenced to MLLW.

20. The breakwater consists of seven rectangular concrete modules, 100 ft long by 16 ft wide by 5.5 ft deep. Module walls are 5.0 in. thick with welded wire reinforcing, and each module is longitudinally posttensioned. The breakwater is held in place by timber anchor piles driven 20 ft into the medium-dense sands below the bay muds as shown in Photo 3. Modules are connected by large rubber fenders bolted between adjacent units. Dredging was

required under the breakwater to a depth of -12 ft MLLW to prevent the structure from striking bottom at extreme low tides and to provide keel clearance for boats at or near the breakwater.

Zittle's Marina (Johnson Point)

21. The pipe-tire breakwater at Zittle's Marina near Johnson Point is a matrix of 16-in.-diam pipes and truck tires held together with conveyor belting (Figure 4). It was constructed by CENPS as part of the Floating Breakwater Prototype Test Program.* The breakwater was damaged as a result of faulty welds during the test and was surplused at the end of the test program. A local marina operator salvaged the breakwater, towed it to the marina, and repaired it. The marina site is approximately 15 miles south of the East Bay Marina, and tides at this location are essentially the same as those given for East Bay. It is completely protected from all directions except an open area to the north with a fetch of about 2 miles (Photo 4). No estimate of wave heights at the site has been made; but because of the limited exposure, wave heights probably do not exceed 3 ft.

Port of Brownsville Marina

22. The Brownsville Marina is located on the Kitsap Peninsula on the western margin of Puget Sound approximately 14 miles west of Seattle, Washington, with an MTL of 6.8 ft, a diurnal range of 11.7 ft, and a maximum range of 19.5 ft. The breakwater, which provides protection from northerly waves (estimated $H_s = 3.2$ ft, $T = 3.4$ sec), was installed in 1981. It is a rectangular concrete pontoon (18 ft wide, 5 ft high) and is composed of 24 units, each 15 ft long. Units are posttensioned together to form a single 360-ft-long float (Photo 5). This float is moored in 10 to 20 ft of water (at a 0.0-ft tide) by stake piles, each attached to a 1.5-in.-diam stud link chain anchor line. No clump weights are attached to the anchor lines, but the oversized chain serves essentially the same purpose as clump weights. A north-south leg of the breakwater is exposed to much smaller waves from the southeast. It is composed of a series of 27 surplus US Navy submarine net floats,

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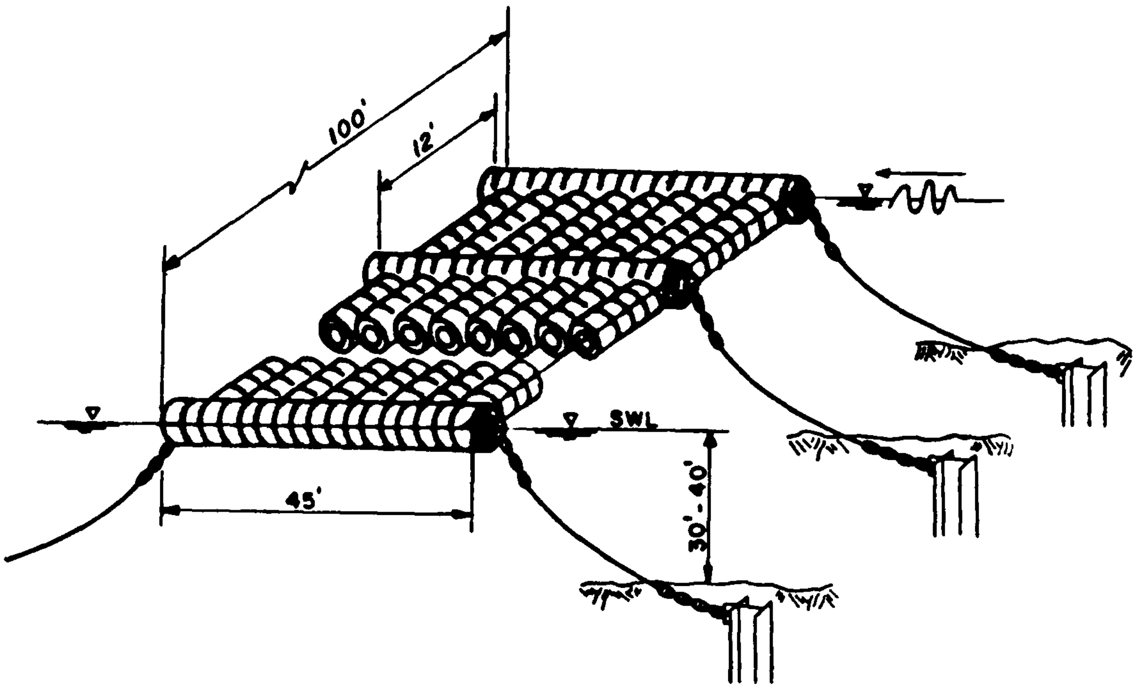
* See paragraph 5.



a. Pipe-tire breakwater (not to scale)

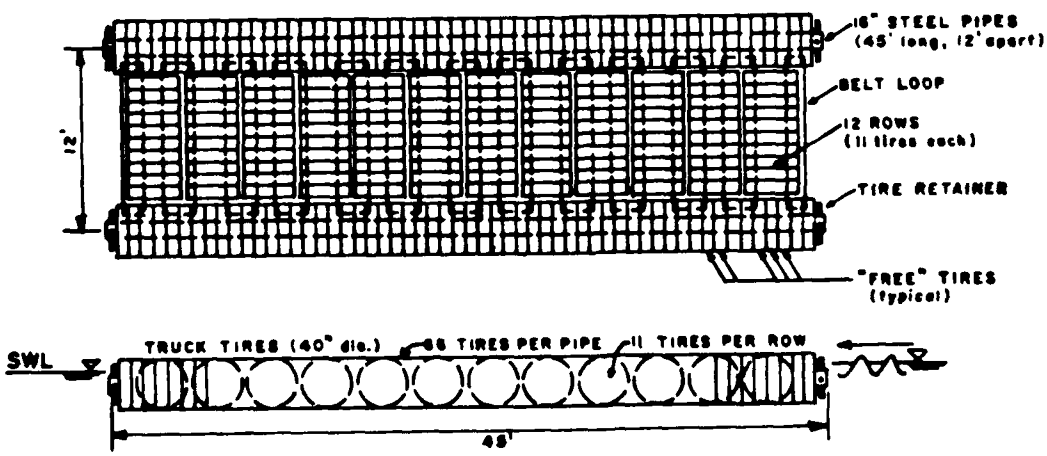


Figure 4. Breakwater at Zittle's Marina near Johnson Point

each 12 ft long and 6 ft in diameter, and a 157-ft-long by 23-ft-wide landing craft ballasted to a 16-ft draft. Floats and landing craft are ballasted with seawater. This makeshift portion of the breakwater is held in place by 3-in.-diam nylon rope attached to the timber piles.

Semiahmoo Marina, Drayton Harbor, Blaine, Washington

23. Since Drayton Harbor is shallow, the marina site had to be dredged to -10 ft MLLW. It is exposed only to the southerly quadrant with a high tide fetch of 1.7 miles to the south and 2.3 miles to the southeast. Mean tide range is 5.7 ft, diurnal range is 9.5 ft, and maximum range is 17 ft. Wind waves used for design are not available but are probably in the 2- to 3-ft range. Exposure to the south and southeast is likely to allow winds of 40+ knots every winter, with 50-knot speeds on occasion.

24. The breakwater, constructed in 1981, is of the concrete caisson type. It was cast in 4.5- by 15- by 15-ft units using polystyrene foam blocks as interior formwork and for positive flotation. The design draft was 3 ft. The total length of the breakwater, arranged in a U-shape, is approximately 3,500 ft (Photo 6). The marina eventually will have 840 slips for pleasure craft and fishing boats.

25. Each basic unit was truck-hauled to the site where four of them were posttensioned together to form 60-ft modules; then the 60-ft modules were coupled by a chain-rubber fender connector. The anchor system uses clump weights on the anchor line consisting of a successive length of 1-in.-diam nylon rope and stud link chain to timber piles (Figure 5) with a set of lines at each module connection.

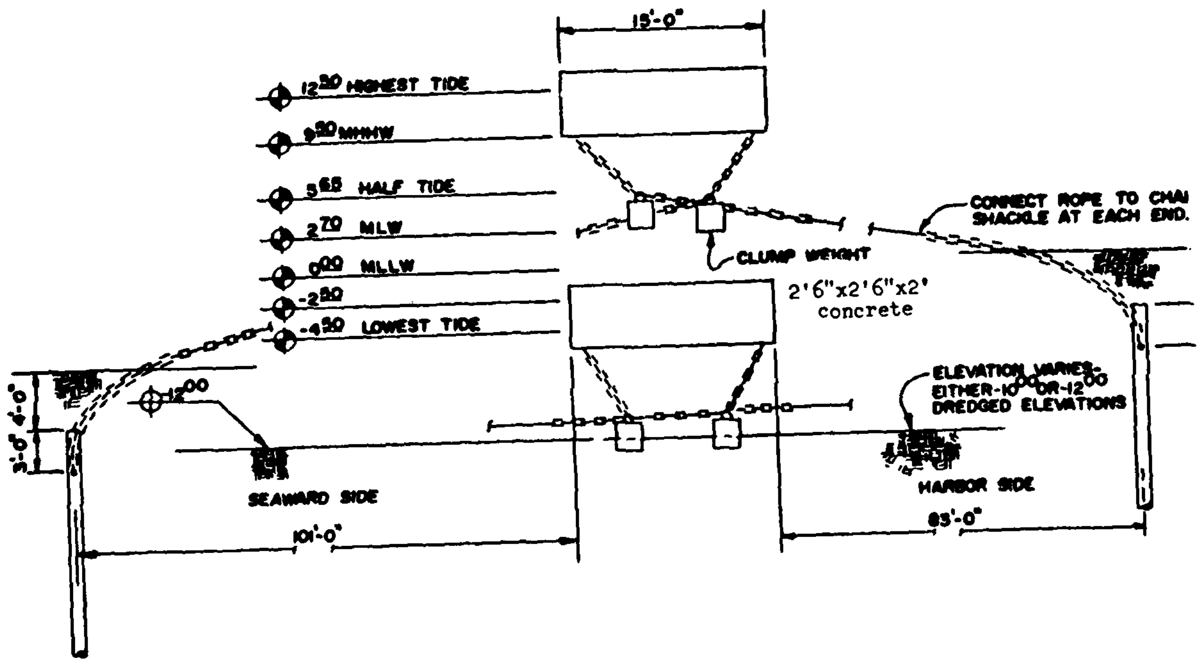


Figure 5. Semiahmoo Marina breakwater anchor system

PART III: MONITORING RESULTS

26. The winters of 1984-85 and 1985-86 were exceptionally calm in the Puget Sound region, and none of the breakwaters monitored were subjected to near-design wave conditions. Only the breakwater at the University of Washington Laboratory at Friday Harbor experienced storm damage.

Port of Friday Harbor Marina

27. The breakwater at Friday Harbor was the most carefully monitored of those in this MCCP Program effort. Inspections were made by CENPS personnel in December 1984, May 1985, October 1985, March 1986, and July 1986. A recording anemometer was installed, and an underwater inspection of the anchor lines was conducted (Photos 7 and 8). In addition, the Port's harbormaster was contacted whenever a storm passed through the Puget Sound region. The only damage to the breakwater itself occured shortly after completion of construction as a result of a collision with a large 110-ft steel pleasure boat. A small piece of concrete on a corner of the C-float was broken off, exposing some of the structure's reinforcing steel. The crude epoxy patch which was used to cover the damaged area remains intact and appears to be successfully protecting the underlying steel (Photo 9).

28. During original planning for the breakwater, the potential for damage caused by boat-generated waves and proximity to the Washington State Ferry System route was cited as the reason no vessels should be moored on the seaward side of the breakwater. As a result, loads for the original breakwater and anchor system design did not include any allowance for additional loading because of vessels moored on the seaward side of the breakwater.

29. After project completion, the Port of Friday Harbor found that there was a considerable demand for moorage on the seaward side, particularly for large (75-ft) vessels (Photo 10). The Port requested that the Corps evaluate a proposal to moor large vessels on the seaward side of the breakwater. Additional loads that could be generated if large vessels were moored on the seaward side of the breakwater were calculated and found to be well within the allowable design criteria. However, safety concerns voiced by the Washington State Ferry System remain an unresolved issue. Finally, no adequate tie-up facilities are available on the seaward side of the breakwater, and if

permanent moorage for large vessels becomes possible, substantial mooring hardware improvements will have to be made because the breakwater receives extremely heavy use. In addition to mooring the capacity crowd of transient pleasure boats in the summer, it has proven to be a popular fishing pier for the local population.

30. Lateral and longitudinal excursions of the breakwater were monitored by noting the extent of marks left on the breakwater by access ramp casters (Photo 11). Maximum longitudinal motion (north-south) was about ± 2.5 ft, and maximum lateral motion (east-west) was ± 6 in. North-south motion was probably increased by the sail effect of larger vessels temporarily moored to the B- and C-floats. Several minor storms from the south did not produce particularly large waves but did have winds in excess of 40 mph and may have been responsible for the maximum north-south excursions.

31. On 17 May 1985, an underwater inspection of a portion of the anchor lines was made to assure that the anticorrosion system was working properly. All the fittings, cable, and chain appeared to be in excellent condition. Surface corrosion of the aluminum anodes had begun as expected. One construction discrepancy was discovered at the joint between the two large 21-ft-wide floats. Lengths of the seaward and landward anchor lines, which cross under the float, had been adjusted during construction. At this location, both the landward and seaward anchor lines from the two floats join a common anchor line forming a "Y". The adjustment resulted in the anchor lines rubbing against each other (Photo 12). While damage to the anchor lines did not appear to be particularly serious, a delay of remedial action would have resulted in continual wear and eventually in failure of one or both anchor lines. For this reason, repairs were carried out on 2 October 1985.

32. The repair involved releasing the seaward anchor line from the breakwater, lowering it under and around the landward anchor line, then reconnecting and retensioning it. Work was carried out with no difficulties, but the procedure did require the use of CENPS' debris boat Puget (105 ft long with a 20-ton capacity crane) and a four-man "hard-hat," or surface-supplied, air dive crew (Photo 13). Total cost for the repair was approximately $10,000. Divers using surface-supplied air with communications linked to the surface were invaluable in adjusting final anchor line tensions to assure there was no contact between the anchor lines.

33. After 2.5 years of operation, the Port of Friday Harbor has

experienced several persistent maintenance problems. Access and interfloat ramps are only 4 ft wide (Photo 14). This width precludes access to the breakwater by electrically powered vehicles. The Port would like to use these vehicles to reduce travel time for the 1/2-mile round trip to the end of the breakwater. Stanchions, located on the breakwater to supply electrical service to transient boats, are relatively tall. Their height, combined with their placement near the edge of the breakwater, make them vulnerable to being knocked over by bowsprits of docking boats (Photo 15). This particular stanchion design is also prone to being pulled over by boaters who neglect to unlug their shore power lines before departing. Electrical junction boxes present another problem. The boxes are mounted flush with the deck, so they fill with water unless access plates are carefully sealed. Much of the hardware which provides mechanical support for the electrical wiring was not designed specifically for use in a marine environment; consequently this hardware is now badly corroded and eventually will have to be replaced.

34. A relatively minor, but persistent, problem involves the bull rail. Blocks supporting the bull rail are held in place with only one bolt. Some of the blocks have rotated and present a hazard to boats tied up alongside (Photo 16). Finally, the Port is aware of at least one incident in which a person fell off the breakwater and had to swim to an adjacent dock because he was unable to pull himself up over the bull rail and onto the deck of the breakwater. Plans are underway to install life rings and possibly add safety ladders at various locations along the breakwater.

35. Virtually no wear or damage was noted on the fenders spearating the floats. All readily measurable dimensions were unchanged, and, except for minor corrosion, all hardware and fasteners were in excellent condition (Photo 17).

University of Washington Friday Harbor Laboratory

36. On 11 February 1985, a southwesterly storm with winds estimated at 35-40 mph caused one of the landward anchor lines of the University of Washington breakwater to part. The last link of the chain broke at the upper connection point. Inspection revealed, additionally, that undersized shackles had been used to connect the stud-link chain to the breakwater connection flange, and severe pitting of the 7-year-old chain was evident, particularly

in the upper 10 ft (Photo 18). The broken line was the shortest of all the anchor lines, and, because it was located in an area that became very shallow at low tide, no clump weight was attached. All anchor lines were replaced in the spring of 1985. Zinc anodes were attached at various places along the new anchor chains in an attempt to reduce the rate of corrosion. An unrelated but interesting note is that numerous large blocks (400-lb displacement) of styrofoam are fastened under the breakwater because it initially had insufficient freeboard. Apparently, the concrete thickness tolerances were exceeded during the breakwater construction resulting in excessive structure weight.

East Bay Marina, Olympia, Washington

37. No northerly winds of any significance occurred at the East Bay site, and no damage has been noted on the breakwater after 3 years of operation. A potential problem, pointed out by the concessioner operating the marina for the Port of Olympia, was that the holes through which the pilings passed were large enough to allow a child to fall between the piling and the float (Photo 19). As a temporary solution, plywood rings were placed over the pilings (Photo 20). Another problem, which did not affect the breakwater but did affect all of the access floats within the marina, was that during one period of extreme cold, numerous waterlines ruptured because of either differential expansion between the floats and polyvinyl-chloride waterlines or the freezing of trapped water. Waterlines on the breakwater were enclosed within the float and were not damaged.

Zittle's Marina (Johnson Point)

38. Since its installation at Johnson Point in 1983, the breakwater has not sustained any damage; however, it has not been subjected to any significant wave action (i.e. over 2 ft). Even in this relatively mild environment, the marina operator feels that the breakwater performs a necessary function of providing protection from wave "chop" and boat wakes. The operator has made some progress in his attempt to refurbish the pipe-tire breakwater by repairing the damaged portions and adding several sections (Photo 21). Flotation of the breakwater is about the same as when it was turned over to him in November 1983 (Photo 22).

39. An attempt was made to remove and inspect foam flotation from approximately 10 tires, but the matrix of tires was so tightly bound that only one piece of foam was recovered. This piece was badly worn, weighing only 4 oz compared to an average of 19 oz initially. Of the tires that were inspected, about 50 percent had no foam at all, 25 percent had badly worn foam similar to the one that was recovered, and 25 percent had intact foam flotation. These results raise a question concerning the necessity for foam in the original design.

40. Observations made during the Prototype Test Program indicated that unfoamed tires tended to sink. These same tires now appear to have adequate flotation and are indistinguishable from the foam-filled tires. Several factors may contribute to this apparent contradiction. First, tidal currents were as high as 2 knots at the Prototype Test Program site. Resultant drag forces tended to pull the breakwater under and, once submerged, the tires may have lost their entrapped air. Since tidal currents are very low at Johnson Point, these forces are no longer at work. Second, the mild wave climate at Johnson Point probably leaves the trapped air undisturbed for longer periods of time, while the large waves at the test sites may have deformed the tires enough to allow loss of some trapped air. Third, during the summer, the breakwater is moored in shallow water where it goes aground at low tide, and the trapped air is replaced with the rising tide. There is little wave action at lower stages of tide, the bottom material is sandy with a little mud, and the sidewalls of the tires are high; therefore, very little sediment is trapped in the tires, and little, if any, weight is added as they sit on the bottom. Although the tires still float at approximately the same level as they did originally, their ability to resist being submerged is considerably less than when originally constructed.

41. During the final inspection in November 1986, the tires between pipes would no longer support a person's weight. Apparently, without foam, the trapped air compresses as the tires are submerged, resulting in decreased buoyancy. If marginally buoyant tires were submerged deeply enough, they could become negatively buoyant. Therefore, in areas where tidal currents are high or wave heights are greater than about 1.5 ft, including some type of incompressible flotation remains a requirement of conservative design.

42. On the two sections the marina operator added to the breakwater, creosote-treated logs were used in place of foam-filled steel pipes, and steel

cable was used instead of conveyor belting to bind the tires together. None of the tires in the new sections had any foam flotation, but they were floating at about the same height as the older section.

Port of Brownsville Marina

43. No damage of significant change has occurred at the Brownsville Marina over the last 2 years. Like the Friday Harbor structure, this breakwater has become a popular fishing platform.

Semiahmoo Marina, Drayton Harbor, Blaine, Washington

44. This breakwater was visited in July 1986. Maintenance problems have been relatively minor over the past several years. This level of attention was reached only after a troublesome "shakedown" period. Considerable effort was required to adjust anchor-line tensions and clump-weight placement to align the breakwater units. Shortly after the breakwater was installed, a severe storm destroyed a large number of the interfloat connections between the 60-ft-long units. The connectors were redesigned using large cylindrical rubber fenders (Photos 23 and 24). These connectors have not required any maintenance since their installation. The 1-in.-diam stud-link chain in the anchor line was scheduled for partial replacement in October 1986. Because the service life of some of the chain was shorter than expected, a corrosion protection system is being considered for inclusion in the replacement plan. The main portion of this breakwater is detached from shore, and no boats moor to the breakwater itself. It has, therefore, become an excellent habitat for sea birds and seals.

PART IV: SUMMARY AND CONCLUSIONS

45. Although none of the breakwaters ~~were~~ subjected to significant storms during the 2 years of monitoring, a number of potentially useful observations were made:

- a. Any large concrete float attached to shore will be used for moorage by large vessels if a demand for dock space exists. Provisions for mooring of large vessels should be an integral part of the breakwater design if there is even a remote chance that the breakwater will be used in this manner;
- b. Concrete floats should be designed with rounded corners to lessen the possibility of damage from impacts;
- c. Design and positioning of electrical service outlets should consider the possibility of damage by docking or departing boats, and electrical junction boxes located on the float should be equipped with drains. All hardware which supports electrical equipment should be specifically designed for marine use;
- d. Without a corrosion protection system, the service life of 1-in.-diam anchor chain is between 5 and 10 years in a temperate marine environment. After 2 years, the aluminum anodes that protect the galvanized steel anchor lines at Friday Harbor appear to be working very well. This type of anchor system may provide a service life that is significantly longer than that of an unprotected chain anchor line. At Pickering Beach, Delaware, synthetic rope was used to moor a floating tire breakwater with good results.*
- e. The necessity for placing foam in all tires of a pipe-tire breakwater is questionable. Although the Prototype Test Program** found that unfoamed tires tended to sink over a period of time, the more recent experience at Johnson Point indicates that foam may not be required where tidal currents and wave exposure are not severe. In addition, the questionable long-term durability of urethene foam makes dependence on this type of foam for flotation a risky proposition. Whether additional or any foam is required for a specific use or site is an important question requiring considerable additional information. An alternative solution is to seal the foam blocks in plastic. The durability of this technique has been demonstrated at a floating-tire breakwater in Lorain, Ohio.

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* P. J. Grace, and J. E. Clausner. In preparation. "Floating Tire Breakwater Tests, Pickering Beach, Delaware," Miscellaneous Paper, US Army Engineer Waterways Experiment Station, Vicksburg, Miss.

** See paragraph 5.

BIBLIOGRAPHY

Richey, E. P. 1982. "Floating Breakwater Field Experience, West Coast," CERC Miscellaneous Report No. 82-5, US Army Engineer Waterways Experiment Station, Vicksburg, Miss.

US Army Engineer District, Seattle. 1980 (Dec). "East Bay Marina Final Detailed Project Report and Final Environmental Impact Statement," Seattle, Wash.

US Army Engineer District, Seattle. 1981 (May). "Floating Breakwater Prototype Test Program, Seattle, Washington, Prototype Design Document," Seattle, Wash.

Photo 1. Friday Harbor floating breakwater

Photo 2. University of Washington floating breakwater

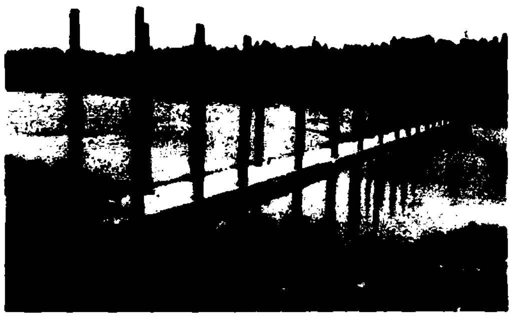

Photo 3. East Bay floating breakwater

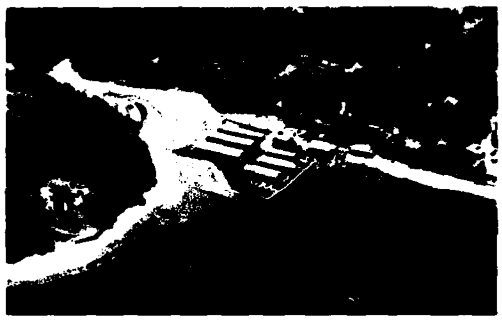

Photo 4. Pipe-tire breakwater at Johnson Point

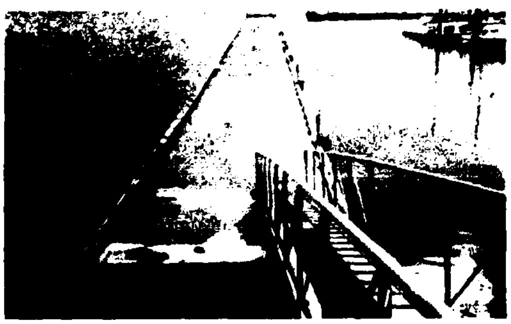

Photo 5. Brownsville floating breakwater

Photo 6. 3,500 ft-long breakwater at Semiahmoo

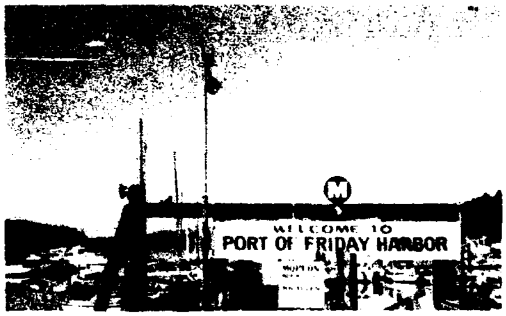

Photo 7. Anemometer at Friday Harbor

Photo 8. Diver preparing to make an underwater inspection

Photo 9. Epoxy patch being placed on breakwater

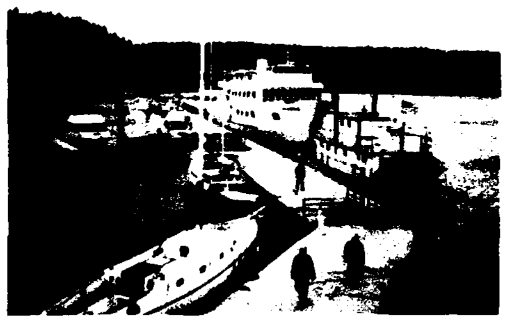

Photo 10. Large vessels moored on seaward side of breakwater

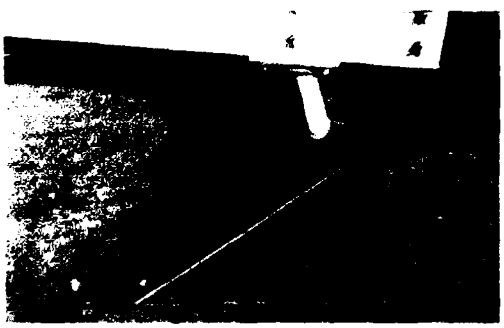

Photo 11. Caster marks indicating limits of motion

Photo 12. Underwater photos of anchor lines rubbing against each other

Photo 13. Breakwater anchor system being repaired by Corps' debris boat Puget

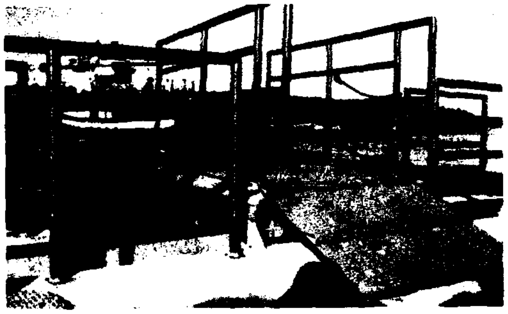

Photo 14. Interfloat ramps

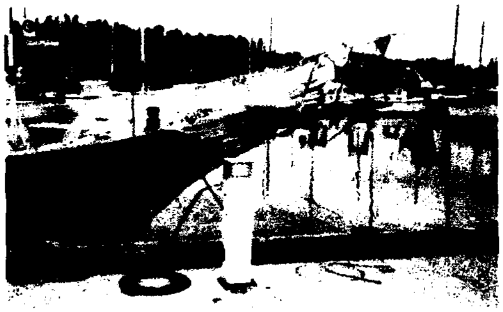

Photo 15. Electrical power post (junction box visible at base of post)

Photo 16. Spacer blocks on bull rail

Photo 17. Fender separating the float

Photo 18. Corroded chain from the University of Washington floating breakwater

Photo 19. East Bay breakwater

Photo 20. Temporary cover for the breakwater-piling gap

Photo 21. Pipe-tire breakwater at Johnson Point

Photo 22. Close-up of pipe-tire breakwater

Photo 23. Cylindrical rubber ship fenders used to connect the floats at the Semiahmoo marina

Photo 24. Close-up of a connector on the Semiahmoo breakwater

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